Ph. D Pre-registration Synopsis

Some Studies on Characterization of Composite Material for Automotive Application.

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on

Some Studies on Characterization of Composite Material for Automotive Application.

For the Doctoral Degree in Mechanical Engineering

Submitted
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1.0 Introduction

The development of mankind is defined in terms of advances in materials i.e. the stone age, the bronze age, and the iron age. The present period of the material belongs to the composite materials because of its lighter weight, corrosion resistance, higher strength, durability and easy to shape. The composites are not new to mankind; it has a history of more than 3000 years. People used to build walls from the bricks made of mud with straw as a reinforcing component [1]. In general, composites are materials which consist of two or more physically distinct and mechanically separable components, existing in two or more phases. The mechanical properties of composites are superior to those of its individual constituents, and in some cases may be unique for specific properties [2]. Usually, composites have two phases i.e. continuous and discontinuous. The discontinuous the phase is usually stronger and harder than the continuous phase and is called the reinforcement and the continuous phase is termed as the matrix. Composites can be classified in two ways i.e. based on the reinforcement used (particle reinforced and fiber reinforced) and based on the matrix used (i.e. polymer matrix, metal matrix, and ceramic matrix). Composite materials have a wide range of applications. They possess applications in buildings and public works (housing cells, chimneys, door panel, partitions, windows, swimming pools, bathrooms and furniture); electrical and electronics (insulation for armor, electrical construction, cable tracks, boxes, covers, radomes, tops of television towers, antennas, and windmills); general mechanical components (bearings, gears, housing, jack body, casing, flywheels, robot arms, pipes, weaving machine rods, components of the drawing table, tubes for offshore platforms, compressed gas bottles and pneumatics for radial frames); rail transports (wagons, front of power units, seat, door, interior panels and ventilation housing); road transports (complete body, body components, shields, wheel,

radiator grills, suspension spring, transmission shaft, chassis, suspension arms, cabin, casing, seats, isothermal trucks, and highway tankers); marine transports (rescue crafts, hovercrafts, trawlers, patrol boats, anti-mine ships, racing boats, canoes pleasure and boats); space transport (rocket boosters, nozzles, shields for atmosphere reentrance and reservoirs); air transports (helicopter blades, all composite passenger aircraft and gliders, transmission shafts, propellers, and aircraft brake discs); cable transports (telecabins and telepherique cabins); sports and recreation (tennis and squash rackets, poles used in jumping, fishing poles, roller skates, bicycle frames, sails, skies, javelins, surfboards and arrows, golf clubs protection helmets and oars), etc.[3].

From a very long time composites have been used to solve the technological problems, but only in the 1960s with the introduction of polymer-based composites, it starts getting the attention of industries. Since then, it has become a common engineering material. The growth in its usage also came about because of increased awareness in terms of product performance and increased competition in the world market for lightweight components [4]. For the past few decades, fiber reinforced polymer (FRP) composites and fiber metal laminates (FML) acquired an important space in the field of composite materials. FRP composites and fiber metal laminates (FML) have been widely used in various applications, i.e. aerospace, automotive, defense, marine, and sports goods because it has high specific strength and stiffness. These materials provide design flexibility, excellent corrosion resistance, high durability and lightweight that make them attractive material in these applications [5], [6]. The fiber which acts as a reinforcing agent in the reinforced plastics may be either synthetic or natural. Various type of synthetic (or man-made) fibers has been developed such as aramid, glass, Kevlar, polyetheretherketone (PEEK), rayon, nylon, acrylic, polyester, olefin, vinyl, etc. On the other hand, some of the known natural fibers are cotton, silk, wool, hemp, ramie, linen, pinewood, coconut, jute, mohair, pineapple, angora, angora, kapok, sisal, flax, kenaf, banana, wood fiber, bamboo, etc. [7]. The metal fiber/plate also acts as a reinforcing agent in the reinforced plastics. Various types of metal are used in the fiber metal laminates like stainless steel and aluminum[8].

2.0 Literature Review

A review of available research and development is done of composite material and its application progressed significantly for the past few decades. Current work attempted to highlight the importance of composite material used for different application in automotive. Since there is a requirement to review previous work to understand the physical and mechanical behaviors of composite material: density, impact, hardness, damping, stiffness, fatigue, adhesive / abrasive wear, different orientation, and stacking sequence were discuss. Ecological awareness and realization improved all over the world have developed the growing attention in composite material and its application in a different area. Nowadays, in different field composite material are considered as a probable option to the conventional material. In the literature review, previous work on hybrid composite with metal and plain composite material applications also discuss to understand the methodology used in design, fabrication, and investigation.

H. Hassulbruch et al studied the properties and failure of composite fabricated of hybrid wire mesh and carbon fiber reinforced thermoplastic under the quasi-static tensile load. Experimental results on carbon fiber reinforced thermoplastic and wire mesh of steel show that these advanced composites sheet can be successfully realized by forming at elevated temperature. This research focuses on the analysis of the relationship between the failure pattern and tensile testing based on the metallographic section. From the study, it concluded that the manufacturing process itself has a considerable impact on the mechanical characteristics of the composites. He has suggested that to obtain improved interface, a pre-treatment of the mesh surface should be performed. A pre-treatment by sandblasting or chemical etching could help to increase the relative reaction surface promoting the micro-mechanical interface of the thermoplastic polymer [9].

Dong Quan et al used ductile stainless steel fibers as an interlayer to improve the interlaminar fracture toughness of carbon fiber reinforced plastic composite. In this study, the stainless steel fibers were incorporated at the center of CFRP's transversely or longitudinally to the crack growth direction. Uniaxial tensile testing and double cantilever beam testing carried out to identify the mechanical properties and fracture toughness of

the CFRP's. From the experimental result, it shows that the significant improvements in the fracture energy of CFRP's were achieved by adding stainless steel fibers [10].

Karunagram N. et al studied the effect of surface treatment for glass fiber, stainless steel wire mesh on flexural, tensile, impact and inter-laminar shear properties of glass fiber / stainless steel wire reinforced epoxy hybrid composites. 1 N solution of sulfuric acid or 1 N solution of sodium hydroxide is used for surface treatment of glass fiber sheet. Electro dissolution or sandblasting is used for surface treatment of stainless steel wire mesh. Hand lay-up technique at room temperature is used to fabricate the composites of glass fiber/epoxy embedded with stainless steel wire mesh. From the experimental results, it shows that the effects of surface treatment on composites were improved as compared to composites without any surface treatment. From the morphological study, it shows that the bonding between the epoxy resin and glass fiber/stainless steel were enhanced, which shows indirectly improve in tensile, impact, flexural and inter-laminar shear properties [11].

P. B. Waghmare et al designed CMLS for the static and modal analysis. FEA used to estimate the deflection, mode frequency and stresses occur in the CMLS used in army jeep. FE analysis shows that the maximum safe payloads considered in design are safe for all conditions. Variation in natural frequency also studied [12].

D. D. Hasbe et al designed and analysis of CMLS for the automotives used for commercial application. The reason behind this study is to design and analysis of CMLS for experimental loading and design conditions. E- GFRC material used to fabricate CMLS and hand lay-up technique used to manufacture CMLS. Finite element analysis was carrying out using ANSYS. Comparative study was done between experimental and FEA for validation. From the experimentation and FEA analysis, it shows that the CMLS has a greater capacity to absorb shock than CSLS. Fiber orientation also effects on the frequency [13].

Chen Qian et al investigated the fatigue behavior of parabolic CMLS. Fatigue reliability of CMLS is a crucial parameter for the analysis of CMLS. Fatigue bench test machine was used for investigation. In this study, the CMLS fabricate by using ply scheme design technique and concept of sandwich unit. Stacking and different length layer sections also studied. Genetic algorithm (GA) optimization method used for stacking sequence. From the experimental results, fatigue weak areas are found out. It also shows that the

intersection between the short and long layers of the CMLS was the weakest portion. From the observation, it shows the initially fatigue crack occurs in the weak region, and then progressively it increases as the fatigue cycle increased. The fatigue life of CMLS is enhanced by varying the stacking sequence of the layer and fatigue weak area. The optimization of the stacking sequence of the layer in CMLS has a noticeable enhancement in fatigue life [14].

Banka H. et al carried out the experimental analysis and fabricated CMLS. Conventional material like aluminum, brass, and steel will fail without any prior information i.e. sudden failure occurs. To avoid such type of problems, conventional material is replaced with the hybrid composite matrix material. A composite material is generally used for high technology applications due to avoid sudden failure issues but nowadays new material requirement also for the application of spring used in Automotives. The objective of this paper is to fabricate hybrid CMLS with the help of different fibers. Epoxy resin and hardener was used as a composite matrix and their mixing ratio is used as per the recommendation. Pro/ Engineering software was used to modal the CSLS and CMLS, then imported in ANSYS software where finite element analysis was done. In present work, the CMLS and CSLS specimens are tested for mechanical properties like strength, stiffness, deflection and bending stress as well as the cost of the spring. From the experimental and FEA results it shows that the cost of material, weight, and stresses in CMLS was less, whereas the stiffness of CMLS was higher [15].

Joo-tech Jeffrey KUEH et al evaluates fatigue and static behavior of CSLS and CMLS using ANSYS. The dimensions of existing and modified CMLS were the same used in light commercial automotive. Two different composite materials were used to fabricate CMLS. E-Glass fiber, epoxy resin, and vinyl ester were used to manufacture CMLS. The purpose of this work predicts the static and fatigue behavior of CMLS. Effect of material composition, composite matrix and fiber orientation also investigated. The result shows that the improvement in static and fatigue performance by CMLS. The maximum bending stress in CMLS is lower as compared to CSLS. E-Glass fiber / Epoxy resin CMLS has a higher fatigue life as compared to E-Glass fiber/vinyl ester CMLS [16].

Ranjeet Mithari et al designed and analysis of CMLS using analytical and FEA. Existing multi-leaf spring was replaced with mono CMLS. FFT analysis was done to find the

frequency of the CMLS. The result shows that the natural frequency of CMLS was higher than the CSLS. Weight of CMLS was reduced by 84.40% as compared to CSLS [17].

Mr. V. K. Aher et al investigated multi-leaf spring for static and fatigue behavior. In this study, the fatigue life of CSLS was predicted, as well as to find the analytical stress and deflection. Finite element analysis predicts the crucial area as per a static loading viewpoint. The result shows that a better correlation between commercial solver and analytical result [18].

Various journal papers were referred for the review and almost all paper concluded that the composite material is lighter, high strength, more economical than conventional material used for spring.

Based on the literature review, it is generally accepted that fiber bridging and filler particles are the main toughing mechanism for fiber interleaved FRPs. From the literature review, it could be noted that limited work has been carried out in the area of hybrid composite laminates especially with steel wire or steel plate used as reinforcement and little attention paid to improve bonding between fiber and metal. It shows that some issues in bonding between fiber and metal in hybrid FML that needs to be the focus so that the performance of the FML enhances.

Research Gap

- The researchers have studied the different plain and hybrid composites such as Carbon/epoxy, Kevlar/epoxy, Glass/epoxy, Carbon-Glass/epoxy, and Carbon-Kevlar/epoxy, etc. but less concentration on fiber-metal composites. Therefore, there is a need for a detailed study of fiber-metal composites.
- It has been reported by the researchers that hybrid composites provide excellent properties but less concentration on the bonding of fiber and metal composites which indirectly enhance the properties of a composite. Therefore, there is a need to study how to improve bonding between fiber and metal composites.
- Very few research efforts have been reported on friction and wear properties of the fiber-metal composites. As fiber-metal composites have several applications in automotive and aerospace etc. Therefore, there is a strong need to investigate, optimization and prediction of the effect of control factors on wear behavior fiber metal composites.

3.0 Research Methodology

3.1 Problem Definition

Based on the research gap as discussed above, it is decided to address research issues such as feasibility of composite material for different application in automotives, investigation of mechanical properties and wear behaviour of plain and hybrid composites for the application in automotives.

3.2 Problem Statement

The aim of this research work is to study and investigate the performance, characterization, friction and wear performance of plain and hybrid composites. Also, effort is made to explore the possible application of developed material in automotive that require improved mechanical properties and good wear and friction properties.

3.3 Materials

Nowadays the automotive industries are trying to decrease fuel consumption continuously. Weight of the vehicle is a crucial parameter for fuel consumption. To improve fuel efficiency, the weight of the vehicle required to be reduced.

Fiber reinforcement polymer (FRP) composites and fiber metal laminates are one of the replacements for various components of automotive. It defines as the material that consists of the fiber and metal mix with the composite matrix (resin and hardener). Effects of fiber contribution will be strength and stiffness. The mixing ratio of fiber and composite matrix may affect on reduction of strength or it may fail early.

FRP composites are extremely ecologically friendly. It reduces the weight approximately 75%, that contributing increasing fuel efficiency of the vehicle. The energy required for manufacturing composite material component is less.

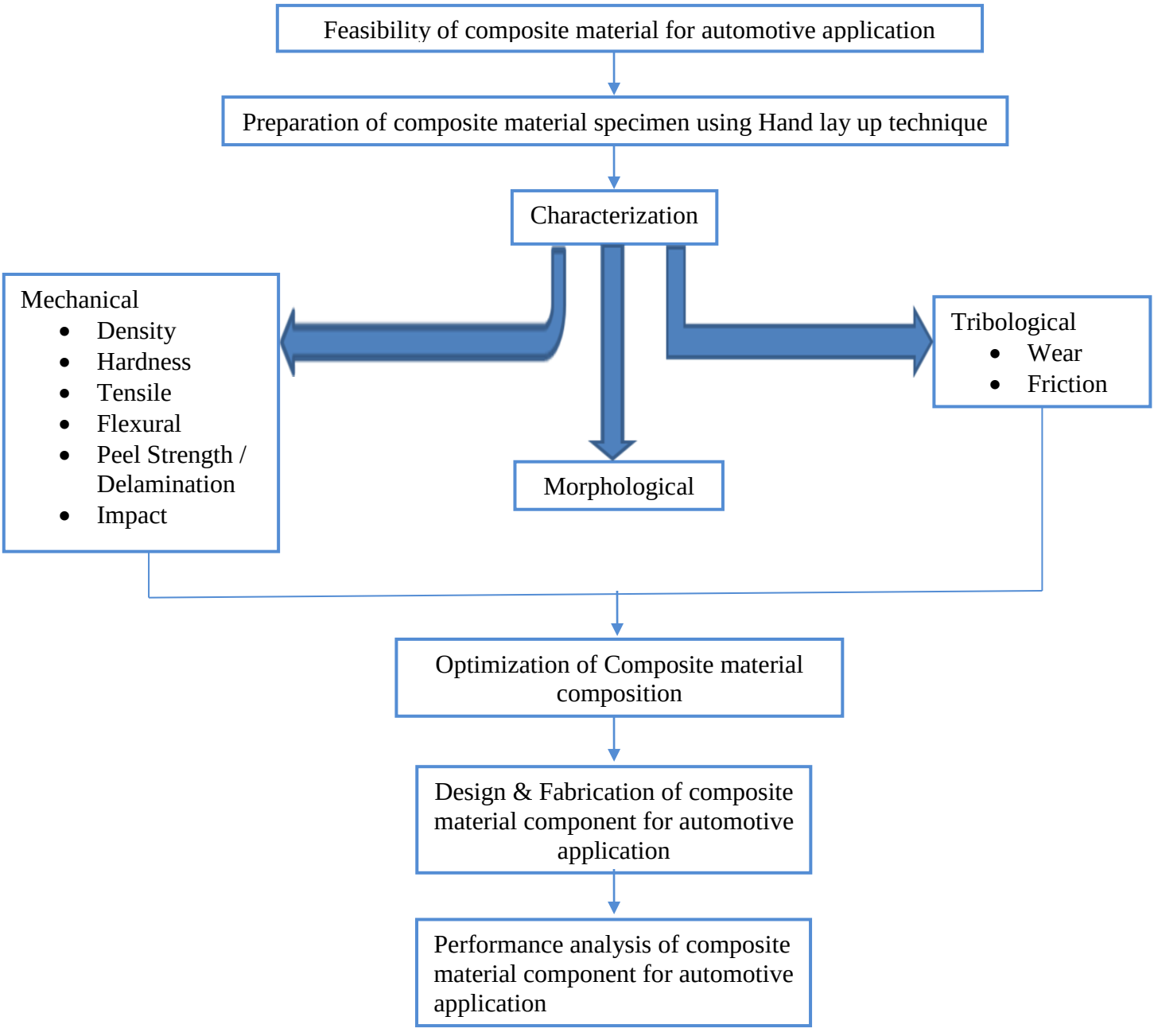
Types of Fiber and Metals

- **Glass Fibers**
  - A-glass (Alkali)
  - C-glass (Chemical)
  - E-glass (Electrical)
  - S-glass (Strength)
  - D-glass (Dielectric)
- **Carbon fiber**
  - Carbon (HM)
  - Carbon (HS)

- ➢ **Kevlar 49**
- ➢ **Aramid**
- ➢ **Aluminum**
- ➢ **Steel wire mesh and plate**

- **Types of Matrix**
  - ➢ **Epoxy**
  - ➢ **Polyester**
  - ➢ **Polyimide**

3.4 Methodology



4.0 Objectives

1. To investigate the feasibility of composite as a material for automotive application.
2. To investigate the physical and mechanical properties of plain and hybrid composite material for automotive application such as density, hardness, tensile strength, flexural strength, impact strength, and fatigue.
3. To investigate the Friction and wear analysis of plain and hybrid composite material using a standard pin on disc machine.
4. To study the surface morphology of the composites.
5. To design, fabrication and performance of composite material component used in automotive.

5.0 Implications / Expected Outcomes

This study consists of an experimental and computational investigation of composite material specimen and component. The proposed work will be an attempt to evaluate the feasibility and performance of composite as a material for an automotive component.

With the proposed work planned to be undertaken, the following expected outcomes are expected to be achieved.

- ➢ Optimized plain composite material or hybrid composite material for automotive application will be identified.
- ➢ Investigation of composite material will be able to compare strength to weight ratio.
- ➢ Performance of composite material for automotive application will be analyzed.
- ➢ Experimental result will be useful to evaluate the properties of composite material.
- ➢ Mechanical properties will be valuable to evaluate strength of composites.

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